Productivity and nutrient cycling in an agroforestry ecosystem for interplant of pineapple and coconut [1)]

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Abstract In this paper, the biomass productivity and nutrient cycling in an agroforestry system of coconut (*Cocus nucifera*) interplanted with pineapple (*Ananas comosus)* had been studied. The result showed that the biomass productivity of this ecosystem was 47 460 kg•hm^{-2}•a^{-1}, which was 4.3 times as much as that of pure coconut plantation. In the biological cycling of N, P, K elements, the total annual retention was 559.470 kg•hm^{-2}, the annual return was 410.745 kg•hm^{-2}, the annual uptake was 970.475 kg•hm^{-2}, respectively. The average circulation rate in three nutrient elements (N, P, K) was 42.32%, which was 27.53% more than that in pure coconut stands. Coconut interplanted with pineapple was proved to be one of optimum cultural patterns, which had the higher biomass productivity, and better usage efficiency of environment resources in tropical areas.

Key words: Agroforestry, Biomass productivity, Nutrient cycling, Coconut, Pineapple

Introduction

Coconut (*Cocos nucifera*) is an important economic plant in the tropical areas. But in the traditional coconut plantation, the routine space in the rows is 7.5 m ×7.5 m. So the field areas about 75% were not efficiently used. In recent years, Indonesia has made great efforts to develop an agroforestry system of coconut interplanted with pineapple (Satyabalan 1986). As the pineapple has a certain amount of shade-resistance, this system can not only make full use of the soil resources, but also greatly improve the biomass productivity of the whole system. But the research about the productive potential and systematic function of the compound pattern hasn't been reported yet. In 1996, from January to October, the author made a series of studies about the biomass productivity and the processes of uptake, retention and return of the nutrient elements (N, P and K) in a five-year-old agroforestry system of coconut interplanted with pineapple, which run by Pulau Sambu Group in Indonesia. He tried to reveal the cycle rules of nutrient elements in this compound system and to supply scientific basic for making a suitable managing methods and improving the productivity in this agroforestry system.

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Materials and methods

Study areas

The work was carried out at the plantation located in Riau Province, Sumatra island, Indonesia (latitude for 0°48′ N and longitude for 102°46′ E, nearly a hundred kilometers from the equator), which run by Pulau Sambu Group (Indonesia). It is typical tropical maritime climate. The average annual rainfall is 2 396 mm. The average annual humidity is more than 90%. The soil is mainly tropical woody peat; the depth of soil layers is over 3 m (Esterle 1991). The plantation was built mainly by developing the coastal marsh with the methods of ditching to discharge water and artificially controlling the underground water level. At first, it was a pure coconut plantation, in recent years; it has been built an agroforestry system of coconut interplanted with pineapple. The coconut is hybrid of tall-straw and short-straw variety; the pineapple is cayenne variety suitable for making can (Pualo 1985). The experiment was conducted in the five-year-old agroforestry system of coconut interplanted with pineapple. The general characteristic of this ecosystem was presented in Table 1.

Methods

Establishment of the plots

We set up a plot of 50 m ×50 m in the five-year-old pure coconut plantation and in the five-year-old coconut interplant pineapple system separately, measured

the height, height under branches, basal diameter, diameter of crown, number of leaves, number of fruits etc. for each coconut tree in plot (Xiong 1994; Peng 1996).

Table 1. General characteristic of agroforestry system

Plant	Age /a	Density /tree·hm^{-2}	Tree height /m	Height under branch /m	Basal diameter /cm	Number of leaves /Number·tree^{-1}	Diameter of crown /m
Coconut	5	16	9.12	2.35	32.8	25	8.91
Pineapple	1.25*	26 000~27 000	0.81		2.1	43	0.78

Note: *--The time for pineapple to ripen is about 15 months.

Measurement of the biomass of coconut

On the basis of investigation for each tree in the plots, the standard plants were chosen according to the methods of equal section area, and the biomass was directly determined by the Monsi's method.

Measurement of the biomass of pineapple

A small plot containing 16 pineapple (4 rows, 4 plants in each row) was chosen, the whole roots of each plant were dug out; the fresh weight of each plant of leaves, stems, roots and fruits was measured; fresh weight was converted into dry weight on the basis of plant samples kept in the oven at 80° for 24 h (South China Agriculture University 1989).

Measurement of the biomass of weeds

All plants from 50 cm × 50 cm quadrates were harvested and sorted out into different plant components, then the biomass was determined like the measurement of pineapple biomass.

Analyzing the chemical composition of plants

Plant samples of each fraction were ground to a powder and passed through 0.5 mm sieve, the N, P and K were analyzed by modified Kjeldahl, Vanado-molybdophosphoric acid yellow color method and flame photometry, respectively (Glover 1986).

Results

Biomass and productivity of agroforestry system

The distribution of different organs of coconut and pineapple

The growth and biomass of different plant in the agroforestry system, pure coconut plantation and pure pineapple plantation were separately measured. The results revealed that there was no obvious difference in growth and biomass of coconut and pineapple between the compound system and the monoculture. In the five-year-old compound system of coconut interplanted with pineapple, as the coconut is short, its canopy hasn't closed, and it has no distinct negative-effect to the growth of pineapple. The competition between two kinds of plants community in the environment resources does not appear clearly now. The biomass and relative percentage of each part of coconut and pineapple were presented in Table 2.

Table 2. Biomass and its distribution in different organs of coconut and pineapple

Plant	Age /a	Biomass /kg					
		Bole	Leave	Flower	Fruit *	Root	Total
Coconut	5	55.73 (26.0)**	69.83 (32.5)	1.68 (0.8)	29.4 (13.6)	58.53 (27.2)	215.7 (100)
Pineapple	1.25	0.14 (7.8)	0.84 (47.7)		0.76 (42.2)	0.06 (3.3)	1.8 (100)

Notes: *--The biomass of fruits of coconut only means the dry weight of fruits remaining in the trees, doesn't include the fruits harvested.

**The number in bracket stands for percentage.

Biomass and productivity

In the agroforestry system of coconut interplanted with pineapple, the systematic biomass includes the biomass of both coconut and pineapple, so its total biomass is higher than the pure coconut plantation, its productivity reaches 47 460 kg•hm^{-2}•a^{-1}, which is 4.2 times as much as that of the pure coconut plantation (Table 3). This shows that the compound operation of coconut interplanted with pineapple efficiently raised the utilization of environmental resources and can get a higher economic yield per unit area.

Biological cycle of nutrient elements in the agroforestry system

Concentration of N, P and K in different plants' organs.

The samples were got in the study area and used for chemical analyses mentioned above. The con-

centration of N, P, and K in each fraction of coconut and pineapple is presented in Table 4. The result shows that the concentration of nitrogen, potassium in all organs of coconut and pineapple is much higher than the concentration of phosphorus. This means that plant must absorb much more nitrogen and potassium than phosphorus to grow normally. The results of soil analyses show that the concentration of nitrogen and potassium in this peat soil is very low (0.04% and 0.001 9%, respectively). The concentration of nitrogen and potassium in soil (especially in the surface soil, Eaterle 1991) is the major factor to control the normal growth and development of plants. So to supply enough nitrogen and potassium to the surface soil is an important way to raise biomass productivity of the system.

Table 3. Total biomass and productivity in different systems

System	Community	Density/tree•hm^{-2}	Biomass/t•hm^{-2}	Productivity/t•hm^{-2}•a^{-1}
Agroforestry system	Coconut	167	35.93	9.3
	Pineapple	26 500	47.70	38.16
	Total		83.63	47.46
Pure coconut plantation	Coconut	180	38.73	9.7
	Weeds		1.14	1.14
	Total		39.87	11.1

Table 4. Concentration of N.P.K in different organs of the plants %

Nutrient element	Coconut				Pineapple				
	Bole	Leaf	Root	Flower	Fruit	Bole	Leaf	Root	Fruit
N	0.346	1.942	0.386	0.448	1.804	0.412	0.845	0.762	0.417
P	0.033	0.131	0.028	0.096	0.097	0.078	0.198	0.172	0.124
K	0.284	0.874	0.395	1.043	1.043	0.425	0.687	0.845	0.727

Annual retention of nutrient elements

Annual retention is the total amount of elements accumulated in plants during one year. It contains the amount fixed in the roots, boles, leaves, branches and flowers of coconut and pineapple, and the amount taken away by harvesting the fruits of coconut and pineapple.

Table 5. Annual retention of nutrient elements in the agroforestry system kg•hm^{-2}

Compartment	N	P	K	Total
Coconut	215.729	13.800	125.643	355.172
Pineapple	67.187	19.987	117.134	204.299
Agroforestry system	282.916	33.778	242.777	559.471

Table 5 shows that the annual retention of nutrient elements in the agroforestry system is 559.471 kg•hm^{-2}, of which, coconut contributes up to 63.48 percent of the total retention (335.172 kg•hm^{-2}), while pineapple only contributes up to 36.52% (204.299 kg•hm^{-2}). The amount of nutrient elements stocked in coconut is the predominant in this agroforestry system. Retention is the best index for determining the amount of fertilizer. It is necessary to supply external nutrient into the system according to the retention in order to maintain the stability of soil fertility and to get higher productivity of the agroforestry system.

Annual return of nutrient elements

In this paper, annual return only includes the amount of elements in litter of coconut, partly cortex of coconut and debris of pineapple, the amount of elements returned by precipitation leaching, dead roots were not calculated because of the experiment condition. The result of annual return is presented in Table 6.

Table 6. Annual return of nutrient elements in the agroforestry system kg•hm^{-2}

Compartment	N	P	K	Total
Coconut	33.014	1.669	18.719	53.423
Pineapple	171.856	39.763	145.703	357.322
Agroforestry system	204.870	41.431	164.422	410.745

Table 6 suggests that the annual return of nutrient elements in the agroforestry system is 410.745 kg•hm^{-2}, in which the amount returned by coconut and pineapple is 53.423 kg•hm^{-2} and 357.322 kg•hm^{-2}, respectively. It makes up 13.01% and 86.99% of the total return, respectively. It is the major way to return nutrient elements in the system that the debris of pineapple returns to system.

Annual uptake of nutrient elements

According to the theory that the uptake equals to the sum of the retention and the return (Duvigneaud 1970; Toky 1989). The annual uptake estimated is presented in Table 7.

Table 7. Annual uptake of nutrient elements in the agroforestry system kg •hm^{-2}

Compartment	N	P	K	Total
Coconut	248.943	15.409	144.362	408.574
Pineapple	239.043	59.741	263.837	561.621
Agroforestry system	487.786	75.210	408.199	970.495

Table 7 suggests that the total annual uptake in the agroforestry system is 970.495 kg•hm^{-2}. The uptake by coconut makes up 42.10%, the uptake by pineapple makes up 58.90%. After the coconut being interplanted with pineapple, 2 times nutrient was absorbed by the agroforestry system. So it is necessary to maintain nutrient balance in the agroforestry system.

Although the niche of the different communities of the agroforestry system in utilization of nutrient is overlapping, the coconut and pineapple is a reciprocal for absorbing different elements. Table 7 reveals that the maximum amount absorbed by coconut is nitrogen, while the maximum amount absorbed by pineapple is potassium. It is very useful for improving the function of the agroforestry system that the different plants in the agroforestry system are reciprocal in absorbing and using nutrient elements. It also shows that pineapple is a good crop suitable for interplanted with coconut from the view of nutrient balance.

The rate of biological cycle of nutrient elements

According to Liebig's principle about the absorption and return of mineral nutrient elements, the nutrient elements of the ecosystem form the biological cycle by the three processes of absorption, retention and return (John 1988; Xiong 1994). The rate of the cycle is indicated by the biological cycle rate. That is:

$$\text{Biological cycle rate} = \frac{\text{Return}}{\text{Absorption}} \times 100\%$$

By calculating the biological cycle rate of the agroforestry system of coconut interplanted with pineapple, and its component is in Table 8.

Table 8. Rate of biological cycle of nutrient elements in the agroforestry system %

Compartment	N	P	K	Total
Coconut	13.27	10.78	12.97	13.08
Pineapple	71.89	66.56	55.22	63.62
Agroforestry system	42.00	55.09	40.28	42.32

Table 8 reveals that the average cycle rate of the nutrient elements in this agroforestry system reaches 42. 32 %, the cycle rate of nutrient elements of pineapple (63.62%) is evidently higher than that of coconut (13.08%). The coconut interplanted with pineapple increased the return of the nutrient elements in the ecosystem, thus increased the cycle rate. In contrast to the pure coconut plantation, the average cycle rate of nutrient elements in the agroforestry system rises 27.53%. To compare with the biological cycling rate of the different element (N, P, K), P is the highest, N and K is lower than P. This further confirms that the biological cycling rates of N, K are the main factors to restrict the growth of plants in the agroforestry system, which is closely related to the serious shortage of N, K in peat. So to raise the productivity of the system must pay enough attention to apply more N, K fertilizer. In practice, applying more N, K fertilizer has increased the growth and economic yield of coconut and pineapple.

Conclusions and discussion

The compound operation of coconut interplanted with pineapple has evidently raised the biomass productivity of the agroforestry system. The biomass productivity of five-year-old agroforestry system has reached 47 460 kg•hm^{-2}•a^{-1}, which is 4.3 times of that in the pure coconut plantation.

The annual retention, return and absorption of the

nutrient elements in the agroforestry system are 559.471, 410.745, 970.475 kg•hm^{-2}, respectively. The average biological cycle rate of the elements is 42.32%, which is 27.53% higher than that of the pure coconut plantation.

The absorption of the nutrient elements by coconut and pineapple complemented each other, which may wholly raise the utilization ratio of nutrient elements in the agroforestry system.

After the coconut was interplanted with pineapple, the debris of pineapple returned to the field, which increased the return of nutrient materials and promoted the cycle rate of the nutrient elements in the system. Therefore, the system is a high-productive one; the coconut fruits and pineapple fruits harvested every year carried away large amounts of nutrient elements. To add enough N, P, K (especially N, K) to the soil and to protect the return of nutrient itself (increasing the return of cortex of coconut) is the guarantee of raising the biomass productivity in the agroforestry system persistent and stable.

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